South Dakota State University
Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Fact Sheets SDSU Extension

3-1-1999

Salt Salinity Tolerance of Common Agricultural Crops in South Dakota: Forages and Grasses/Grains and Field Crops

John Bischoff
South Dakota State University

Hal Werner

South Dakota Extension
Fact Sheet 903

SALT SALINITY TOLERANCE

of Common Agricultural Crops in South Dakota

Forages and Grasses / Grains and Field Crops

by John Bischoff, assistant professor, Water Resources Research Institute,
and Hal Werner, professor and Extension irrigation specialist,
SDSU Agricultural Engineering Department

Salt Tolerance

Plants vary tremendously in their ability to tolerate salt in water. Their growth can be restricted by the stress of "pulling" water away from the salt. Salt tolerance -- salinity -- is one of several stresses that limit plant growth.

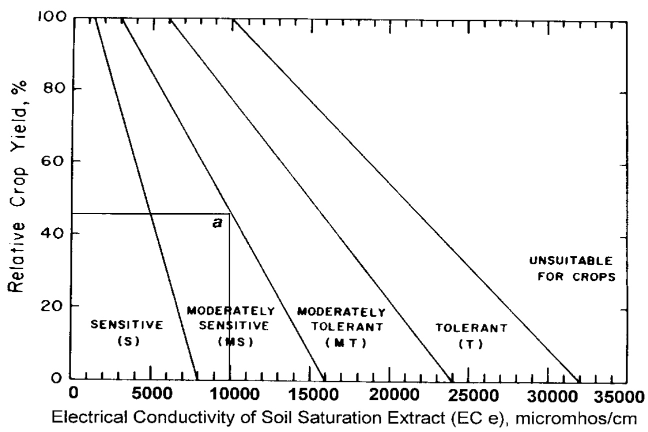
The salinity stress referred to in this fact sheet is the osmotic stress that limits the availability of water stored in the soil. This publication does not consider the permeability problem caused by sodium that reduces the amount of water put into storage. For more information on types of salt problems and what can be done about them, refer to Extension Circular 908 (1998) Identifying and Solving Natural and Irrigated Soil Salinity / Sodicity Problems in South Dakota.

Separating salinity stress from other plant stresses is difficult because increased salts alter the ionic chemical balance in plants and affect water availability to plants. Therefore, salinity problems may contribute to other classes of plant stress.

A relationship of relative crop yield compared to the salinity of the soil solution (electrical conductivity of a soil solution extract) is shown in Figure 1. These empirical relationships are based on experiments using seedlings. The classes are sensitive (S), moderately sensitive (MS), moderately tolerant (MT), tolerant (T), and unsuitable for crops.

To use Figure 1, read the value of the soil salinity on the horizontal axis and follow it upward until it intersects the upper right hand line of the SALT TOLERANCE CLASS for the crop that interests you. Then draw a line horizontally left to intersect the vertical "relative yield" axis and read the number. This would be the percent yield obtainable with these salt conditions.

Figure 1. Relative crop yield compared to the salinity of the soil solution.



If your line does not intersect an upper right line for the salt tolerance class, there would be no yield reduction from salinity. An example of a moderately sensitive crop and a soil salinity value of 10,000 micromhos/cm is shown as a line in Figure 1. Follow up from 10,000 (on the horizontal axis) to the MS line, then draw a line to the left to get about a 45% relative crop yield. This yield would be the highest you could expect for a moderately sensitive crop at this level of soil salinity.

Factors Influencing Salt Tolerance

Growth stage of the plant is very important when considering salt tolerances. Many plants are extremely sensitive to soil salt during germination or in the early seedling stage. Most experiments have evaluated salt tolerance only on more mature plants.

COOPERATIVE EXTENSION SERVICE
SDSU
South Dakota State University
College of Agriculture & Biological Sciences / Water Resources Research Institute / USDA

Varieties and rootstocks of specific crops can be quite sensitive to salt. Be sure to read the footnotes in the tables regarding salt tolerances and variety differences. Some varieties are known to be much more tolerant than others within the same species.

The nutrition level of the plant (i.e. soil fertility) when under stress may affect the plant's ability to tolerate salt. Fertilization usually improves a plant's ability to tolerate salt. Fertilization beyond the plant's needs, however, does very little to improve salt tolerance. Excessive fertilizer, which can be salt-based, may even contribute to soil salinity.

Climatic environment has much to do with a plant's ability to tolerate salt. High temperature, low humidity, and high winds increase evaporation and make the plant more susceptible to salinity; this can cause symptoms similar to water stress. High air humidity benefits salt-sensitive crops more than salt-tolerant plants. High temperatures decrease any plant's ability to tolerate salt.

Chemical ion toxicity affects plants that may be sensitive to specific individual ions. It may affect the plant either by climatic air or water carriers or through the soil. Boron is an ion that some plants are very sensitive to in low concentrations. In South Dakota, aquifers with high concentrations of sodium also may have high concentrations of boron.

Nutritional imbalance as a result of too much salt may occur if some salts are in a certain proportion. For example, high concentrations of calcium sulphate ($CaSO_4$) may tie up some phosphates into complexes that are too insoluble for plants to use.

Soil and Water Analyses

Salinity (soil salt levels) can be determined by testing. Sample soil depths by layers to help determine if and where salts occur in the greatest concentrations. Shallow soil depths can be sampled with a spade during moist conditions. Deeper root zones can be sampled easier with a hand soil probe or truck-mounted soil sampler. Collect composite samples throughout the field to get a representative average of the field. If there are trouble spots that you suspect are caused by salt conditions, sample them separately from the rest of the field. Send soil samples to the Soil Testing Laboratory, SDSU, Box 2207A, Brookings, SD 57006. The phone number is (605) 688-4766.

To determine how much salt is in the water you are using to irrigate, collect a representative pint of water and send it to the Water Quality Lab at SDSU. The lab will analyze your water sample for types and levels of salts and interpret the compatibility of the water with general soils. Contact the Lab at 605-688-4211, Box 2120, SDSU, Brookings, SD 57006, or on the Internet at **www.abs.sdstate.edu/labs_services/wql** for lab costs.

Salt Management

Drainage

Salt problems often occur in soils of poor internal drainage. Low permeability layers restrict the flow of water "out the bottom" much slower than evapotranspiration (ET) removes water "out the top." In such situations, choose crops that can tolerate the salt without much yield reduction, and/or, install artificial drains to allow the removal of leaching water and salts from soils. If artificial drain lines are installed, do it according to county, district, or state drainage laws to prevent passing a salt/water problem from one landowner to another.

Irrigation

Irrigation management can be used to decrease the level of salts in the root zone of the crop. As the salinity of irrigation waters increases and seasonal rainfalls decrease, the window of management for salt becomes smaller and smaller.

Permeability of the subsurface soils is important for salt management. There is a battle between moving sufficient salts downward beyond the root zone and evapotranspiration bringing water and salts back toward the surface.

The balance of salts can be better monitored if the SOIL WATER is known, since the salts move with the water during the irrigation season. Tensiometers or moisture blocks can be used to monitor the soil water at different depths. Refer to Extension publications FS 876, Irrigation Management: Measuring Soil Moisture, and FS 899, Irrigation Management: Using Electrical Resistance Blocks to Measure Soil Moisture, for more information on monitoring soil water.

When you manage irrigation water to reduce salts, remember that other mobile chemicals can move with the water also. Refer to Extension publication FS 864, Nitrogen Management and Groundwater Quality in South Dakota, to help you balance the loss of mobile nutrients with leaching water. See FS 878, Questions and Answers Concerning Agriculture's Impact on Groundwater in South Dakota, for more information on leaching water effects on groundwater quality.

Salts in the root zone are dynamic and tend to change with climatic changes. For well-drained soils, wetter periods tend to push salts further down in the root zone, whereas drier periods bring salts nearer to the surface.

In poorly drained soils, wetter periods tend to bring the water table closer to the surface. In wetter conditions, the salt moves with the water (upward) as the water table rises. Poorly drained soils usually have higher salinity in wetter periods than during a drought. If these facts are known, selection of crops for planting according to their salt tolerance can be used according to climate cycles and soil drainage classification. Obviously, planning for annual crops is easier than for perennials.

When irrigation water is used to replenish soil profiles during the growing season, salt is associated with both surface and groundwaters. Even water considered good for irrigation in South Dakota of 810 micromhos/cm electrical conductivity (600 milligrams per liter) would have 0.82 tons of salt for every acre-foot of water. Refer to South Dakota Agricultural Experiment Station Bulletin 13, Irrigation: Your Water, Your Soil, and their Compatibility, for more information on soil and water compatibility for irrigation.

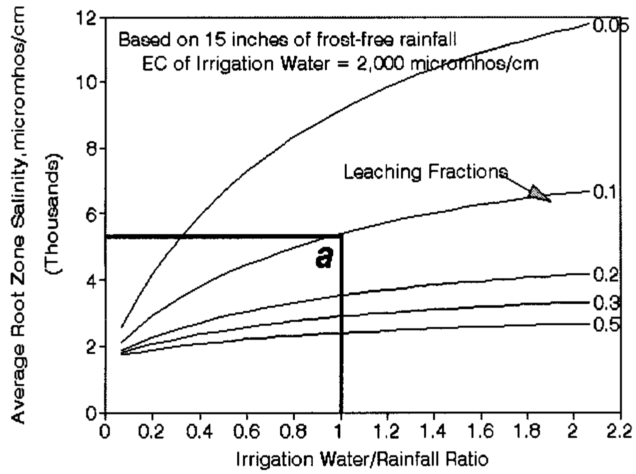
Irrigation adds salt to the soil with the water. The more soluble salts such as sodium sulfate ($NaSO_4$), sodium bicarbonate ($NaHCO_3$), sodium chloride (NaCl), and magnesium chloride ($MgCl_2$) cause more plant stress than less soluble salts such as calcium sulfate ($CaSO_4$), magnesium sulfate ($MgSO_4$), and calcium carbonate ($CaCO_3$). Therefore, some of these salts may need to be managed more carefully to prevent buildup in the root zone.

If natural leaching does not occur, leaching with irrigation water on better drained soils can help move salts downward where they do less harm to growing crops. The “leaching fraction” is defined as the amount of water pushed past the bottom of the root zone DIVIDED by the total amount of water received into the soil. Unfortunately, the leaching fraction is very much controlled by the existing subsurface soils and geology, and finer-textured soils are more difficult to manage for salts because the response time to leaching may span years compared toonly weeks for outwash (coarse subsoils).

Figure 2 shows the relationship between average root zone salinity, irrigation water and rainfall depths, and leaching fractions for a given irrigation water salinity of 2,000 micromhos/cm (high salinity). The average root zone salinity is based on a weighted crop water use of 40% from the top quarter of the root zone, 30% from the second quarter, 20% from the third quarter, and 10% from the bottom quarter of the root zone.

As the amount of irrigation water applied increases and rainfall decreases, the irrigation water/rainfall ratio (IW/RF) increases, the average root zone salinity increases, and a higher leaching fraction is needed to keep salt levels below a certain point. Figure 2 is based on receiving 15 inches of frost-free rainfall during the growing season. This is a good average number to use for central South Dakota.

Figure 2. Relationships of average root zone salinity, leaching, irrigation, and rain depths.



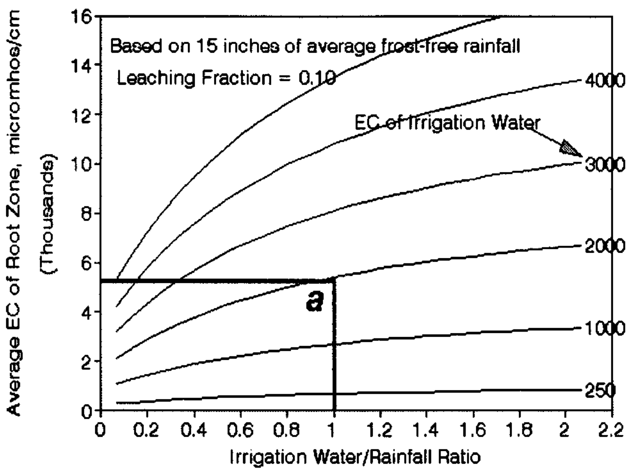
Generally, the average soil salinity values in Figure 2 can be considered as a maximum for South Dakota. Many of the salts in the state are gypsum ($CaSO_4$) that precipitate out at lower concentrations, and upward movement of water as the soil freezes in the winter “distills” some of the soil water.

There is considerable salt removal over the winter months as vapor moves up through the soil profile during freezing conditions living the salts behind. The quantitative extent of the “distilling” depends upon the water table position, the soil moisture content, depth of snow cover, and soil texture. Not much is known about the salt exclusion phenomenon in areas where soils become frozen, but something happens that keeps salts below the root zone in many cases of long-time irrigated fields in South Dakota. Rarely do soils reach the higher levels of salts as shown in Figure 2 when irrigated with high-salinity waters. Salt precipitation and freezing conditions appear to account for much of the reduction in salinity levels in soil profiles in South Dakota.

Frost-free rainfall varies considerably over the state from a high of 20 inches in the southeast to 10-14 inches in the northwest. Therefore, the IW/RF ratio for the southeast for corn may be around 0.6, whereas, it may be closer to 2.0 in the northwest. Two reasons account for a tremendous difference in potential soil salinity:

- More water applied contributes to more salt.
- There is less dilution of soil water from salt-free rainwater.

Figure 3. Relationships of average root zone and irrigation water salinity and irrigation and rainfall depths.



Average leaching fractions under non-irrigated conditions will vary from almost zero in northwest South Dakota with tight subsoils, to as much as 0.4 in eastern South Dakota under high spring rains over shallow soils with coarse subsoils and deep water tables.

Figure 3 shows the relationships of average root zone salinity and irrigation water salinity for various salt levels in irrigation water for a constant leaching fraction of 0.10. Figure 3 is based on 15 inches of frost-free rainfall. The rainfall amount is constant in the IW/RF ratio. This graph shows how low salt waters are much easier to manage than higher salt waters. For example, an irrigation water of 250 micromhos/cm changes very little in average root zone salinity over the ranges of IW/RF, whereas, a water of EC of 3,000 micromhos/cm varies by more than three times (from 3,000 to about 10,000) over the IW/RF range.

Use Figures 2 and 3 to consider an example for corn in central South Dakota. Assume that a corn crop needs 30 inches of water to obtain expected yields. If 15 inches of IW with a water quality of 2,000 micromhos/cm is applied and 15 inches of frost-free rainfall is received, the IW/RF ratio is 1.0. If a leaching fraction of 0.10 is assumed (for every 10 inches of water applied at the surface, 1 inch is lost below the root zone), then an average soil salinity of approximately 5,400 micromhos/cm is approached for steady state conditions. This assumes no precipitation of salts, no uptake by plants, no horizontal flow, or no "distilling" of the water by freezing conditions during winter months. As can be seen from Figure 2, for high salinity waters (2,000 micromhos/cm, or 2.0 tons of salt per acre-foot of water), the average soil salinity can go up rapidly even when 10% of the water is lost out the bottom of the root zone.

Tolerant Crops

The salinity level of the soil at which reductions in yield could be expected for individual South Dakota crops, assuming all other stresses are not limiting, is shown in Tables 1 and 2. This is the "threshold" salinity level or the 0% yield reduction column. The columns relate the expected YIELD REDUCTION if the salinity is at a given level over the season.

The MAXIMUM column signifies the soil salinity level of the root zone -- rooting depth associated with various crops -- at which little to no yield can be expected. The root zone for alfalfa may be up to 10-12 feet deep, whereas for wheat and bermudagrass it may be only 2.5 -3 feet deep. Implement reclamation procedures before this level of salinity is approached, or grow more salt tolerant crops.

Common Forages and Grasses

Tall wheatgrass, crested wheatgrass, wildrye, saltgrass, alkaligrass, barley, and ryegrass top the list for being the most salt tolerant common grasses in South Dakota (see Table 1).

Consider sudangrass as an example. If the average soil salinity of the root zone for the entire growing season was around 5,100 micromhos/cm, you could anticipate approximately a 10% reduction in potential yield (10% yield reduction column for sudangrass is 5,100). If your yield goal for sudangrass were 6 tons per acre, salt levels of 5,100 would reduce the maximum yield to 5.4 tons per acre [(100% - 10%) x 6 = 5.4].

Common Grains and Field Crops

Barley, sugarbeets, triticale, and wheat are the most salt tolerant grain and field crops in South Dakota. Flax and corn are among the crops more sensitive to salts (see Table 2).

Consider wheat as an example. If the average soil salinity of the root zone for the entire growing season was around 9,500 micromhos/cm, you could anticipate approximately 25% reduction in potential yield (25% yield reduction column for wheat is 9,500). If your yield goal for wheat were 60 bushels per acre, salt levels of 9,500 would reduce the maximum yield to 45 bushels per acre [(100% - 25%) x 60 = 45].

Table 1. Salt tolerance for common forages and grasses in South Dakota. Salinity level (micromhos/cm) for different yield loss columns of various crops. Yield decrease to be expected for certain crops due to soil salinity[a].

CROP	RATING[b]	0% EC_E[1]	10% EC_E	25% EC_E	50% EC_E	MAXIMUM EC_E
Alfalfa	MS	2000	3400	5400	8850	15700
Alkaligrass, Nuttall	T*	——	——	——	——	——
Alkali sacaton	T*	——	——	——	——	——
Barley (forage)	MT	6000	7400	9500	13000	20000
Bluestem, Angleton	MS*	——	——	——	——	——
Brome, Mountain	MT*	——	——	——	——	——
Brome, smooth	MS	——	——	——	——	——
Canarygrass, Reed	MT	——	——	——	——	——
Clover, alsike, ladino, & red	MS	1500	2350	3600	5700	9800
Clover, Berseem	MS	1500	3250	5900	10300	19000
Clover, Hubam & sweet	MT*	——	——	——	——	——
Clover, White Dutch	MS*	——	——	——	——	——
Fescue, tall & meadow	MT	3900	5800	8600	13300	22800
Foxtail, meadow	MS	1500	2500	4100	6700	12000
Grama, blue	MS*	——	——	——	——	——
Orchardgrass	MS	1500	3100	5500	9600	17600
Ryegrass, perennial	MT	5600	6900	8900	12200	18800
Saltgrass, desert	T*	——	——	——	——	——
Sudangrass	MT	2800	5100	8600	14400	26000
Timothy	MS*	——	——	——	——	——
Trefoil, narrowleaf birdsfoot	MT	5000	6000	7500	10000	15000
Vetch, common	MS	3000	3900	5300	7500	12000
Wheat (forage)[c]	MT	4500	8300	14100	23700	43000
Wheat, Durum (forage)	MT	2100	6100	12100	22100	42100
Wheatgrass, standard crested	MT	3500	6000	9800	16000	28500
Wheatgrass, fairway crested	T	7500	9000	11100	14700	22000
Wheatgrass, intermediate & slender	MT	——	——	——	——	——
Wheatgrass, tall	T	7500	9900	13500	19400	31300
Wheatgrass, western	MT*	——	——	——	——	——
Wildrye, Altai & Russian	T	——	——	——	——	——
Wildrye, beardless	MT	2700	4400	6900	11000	19400

[a] These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices.

[b] Ratings are S=sensitive; MS=moderately sensitive; MT=moderately tolerant; T=tolerant to salts.

[c] Data from one cultivar, “Probred.”

[*] Ratings with an * are estimates.

[1] EC_E = Electrical Conductivity of the saturation extract of the average root zone (micromhos/cm).

Table 2. Salt tolerance for common grains and field crops in South Dakota. Salinity level (micromhos/cm) for different yield loss columns of various crops. Yield decrease to be expected for certain crops due to soil salinity[a].

CROP	RATING[b]	0% EC_E[1]	10% EC_E	25% EC_E	50% EC_E	MAXIMUM EC_E
Barley[c]	T	8000	10000	13000	18000	28000
Bean	S	1000	1500	2300	3600	6300
Broadbean	MS	2600	2600	4200	6800	12000
Corn	MS	1700	2500	3800	5900	10000
Cowpea	MT	4900	5700	6800	8900	13000
Flax	MS	1700	2500	3800	5900	10000
Millet, foxtail	MS	——	——	——	——	——
Oats	MT*	——	——	——	——	——
Rye	MT*	——	——	——	——	——
Safflower	MT	——	——	——	——	——
Sorghum	MT	6800	7400	8400	9900	13000
Soybean	MT	5000	5500	6200	7500	10000
Sugarbeet[d]	T	7000	8700	11000	15000	24000
Sunflower	MS*	——	——	——	——	——
Triticale	T	——	——	——	——	——
Wheat[c]	MT	6000	7400	9500	13000	20000
Wheat, semidwarf[e]	T	8600	12000	17000	25300	42000
Wheat, Durum	T	5900	8500	12500	19000	32000

[a] These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending on climate, soil conditions, and cultural practices.

[b] Ratings are S=sensitive; MS=moderately sensitive; MT=moderately tolerant; T=tolerant to salts.

[c] Less tolerant during emergence and seedling. Salinity at this stage should not exceed 4000 or 5000 micromhos/cm.

[d] Sensitive during germination. Salinity should not exceed 3000 micromhos/cm.

[e] Data from one cultivar "Probred."

[*] Ratings with an * are estimates.

[1] EC_E = Electrical Conductivity of the saturation extract of the average root zone (micromhos/cm).

More Information

For more information regarding the salinity tolerances of plants, contact:

Water Resources Institute
SDSU, Box 2120
Brookings, SD 57006
Phone: 605-688-4910 Fax: 605-688-4917
E-mail: wrisdsu@mg.sdstate.edu
Internet: www.abs.sdstate.edu/wrri

For more information regarding irrigation management:

Hal Werner, Extension Irrigation Specialist
Box 2120, SDSU
Brookings, SD 57007
Phone: 605-688-5673 Fax: 605-688-6764
E-mail: wernerh@www.ces.sdsdate.edu

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the USDA. Larry Tidemann, Interim Director of Extension, Associate Dean, College of Agriculture & Biological Sciences, South Dakota State University, Brookings. Educational programs and materials offered without regard for race, color, creed, religion, national origin, ancestry, citizenship, age, gender, sexual orientation, disability, or Vietnam Era Veteran status.

1,000 copies printed by CES at a cost of 44 cents each. March 1999.